Space Dynamics Laboratory
Utah State University Research Foundation

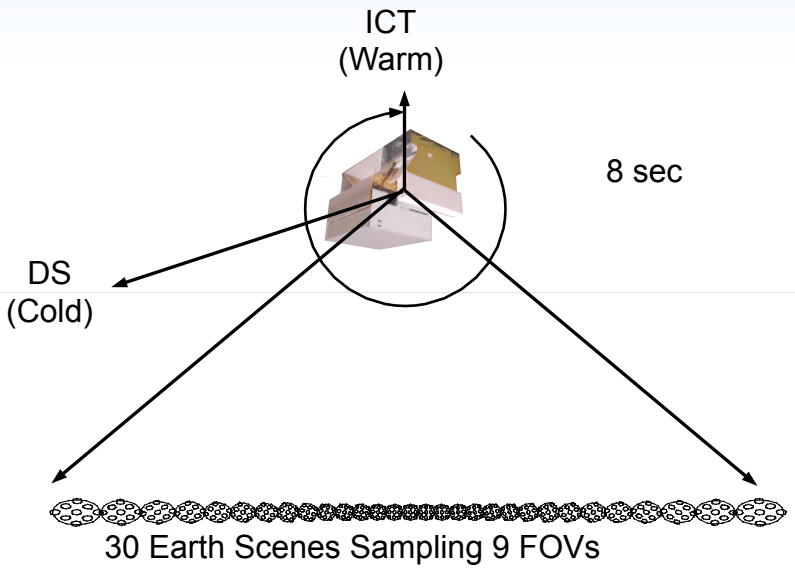
CrIS Internal Target Emissivity Check From Day in the Life Test Data

NASA Sounder Science Team Meeting

Mark Esplin, Kevin Grant, Vladimir Zavyalov, and Chad Fish

CrIS Sensor On The NPP Satellite

- 8-second scans
- 30 Earth locations
  - 9 FOVs per location
  - 3 spectral bands per FOV
    - LWIR 650-1095 cm^{-1}, resolution: 0.625 cm^{-1}
    - MWIR 1210-1750 cm^{-1}, resolution: 1.25 cm^{-1}
    - SWIR 2155-2550 cm^{-1}, resolution: 2.5 cm^{-1}

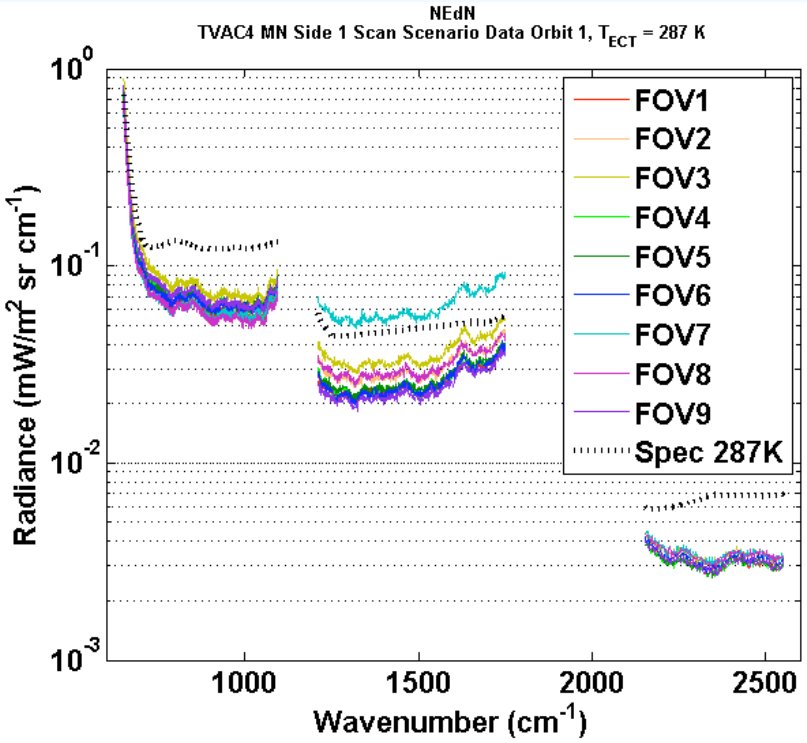


- Two calibration views per scan
  - Internal Calibration Target (ICT) — Warm (ambient temperature)
  - Deep Space (DS) — Cold
  - Separate calibration for two interferometer scan directions
- CrIS has completed thermal vacuum testing and is now undergoing spacecraft integration

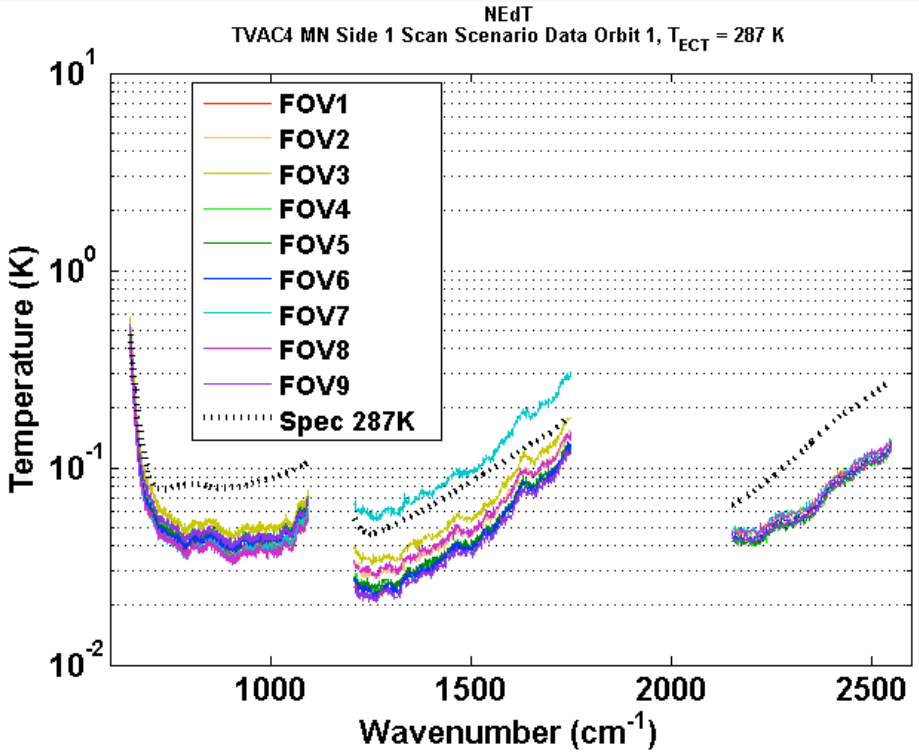
Day in The Life Test

- Also know as the Scan Scenario test
- Scene scan module and electronic box temperatures driven through 3 simulated orbits
- Voltage varied representative of on-orbit bus voltage
- Primary purpose was to provide a flight like data set to test software
- Analysis of TVAC3 data showed a problem with the ICT temperature sensing electronics
- TVAC4 performed to validate modifications to the electronics
- Opportunity to try out Cal/Val type techniques

Noise Performance During Scan Scenario



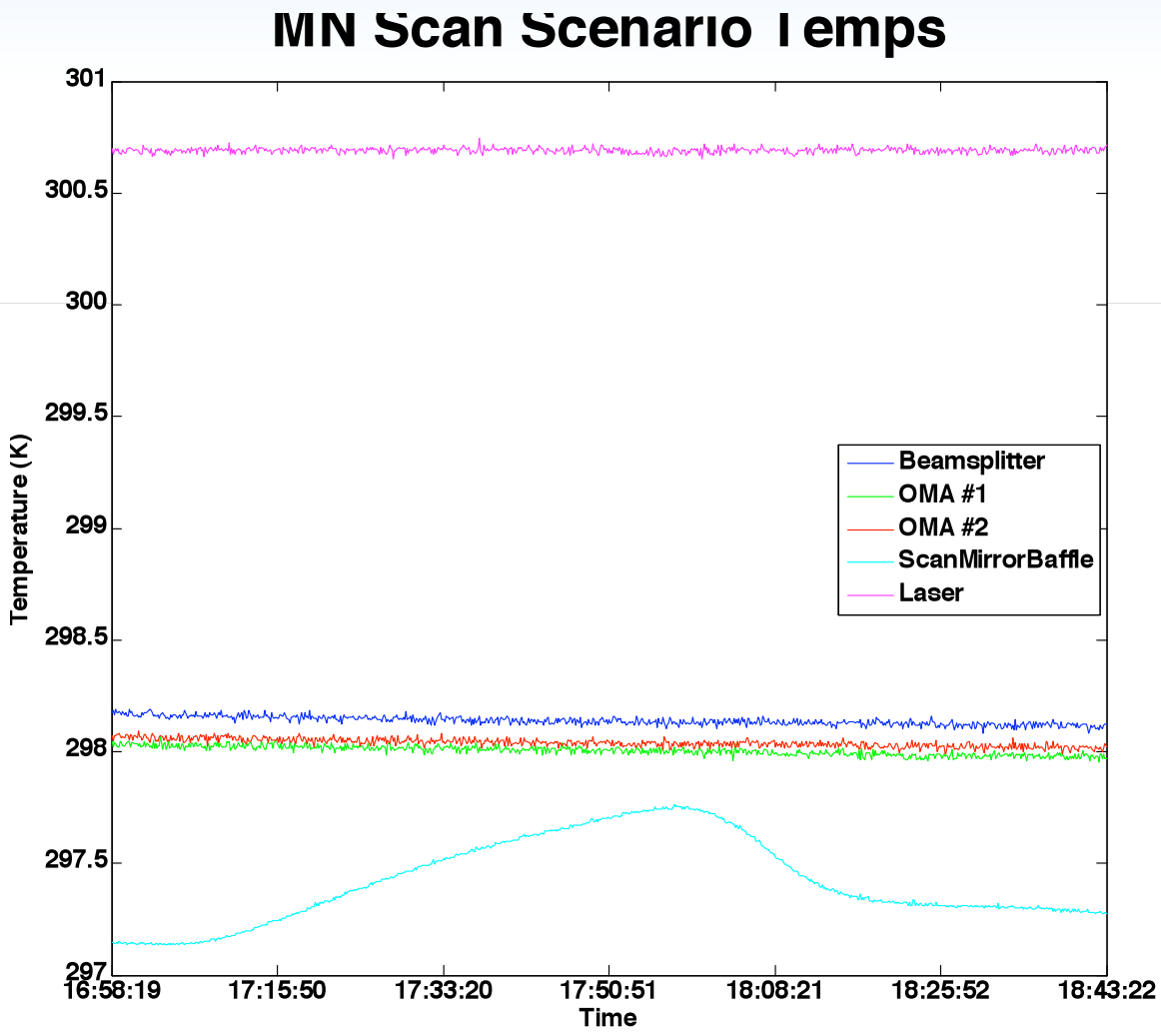
NEdN



NEdT

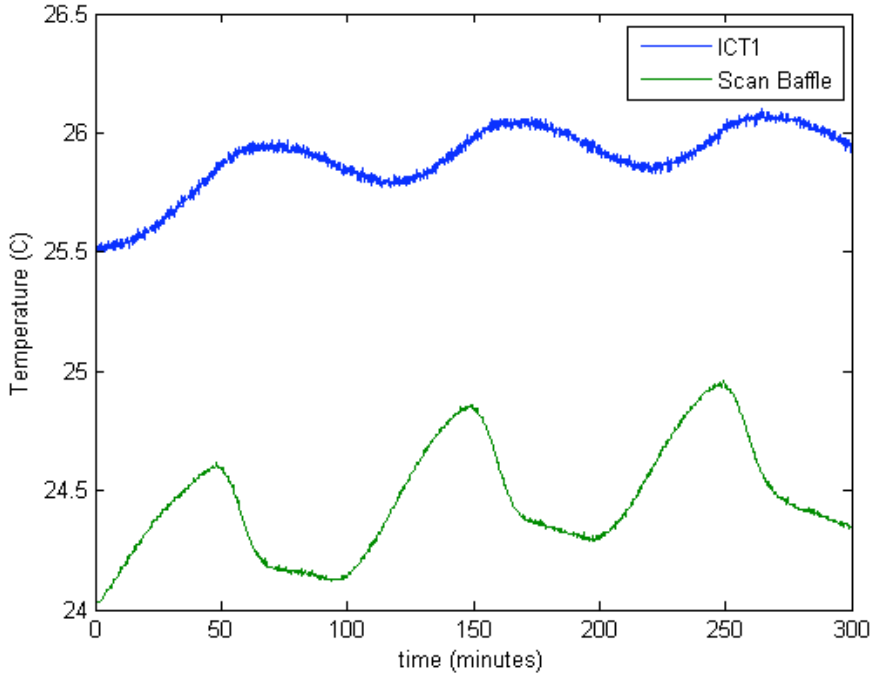
- Measured brightness temperature variations were small compared to random noise
- Substantial averaging was needed to see any radiance errors

Temperature of Sensor Components Over One Simulated Orbit

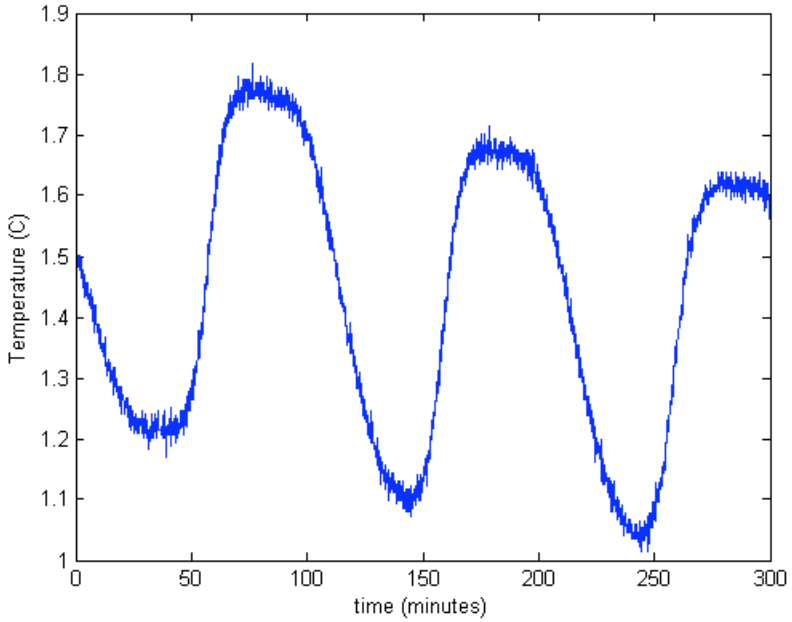


- Radiance from the environment of ICT can be reflected into the interferometer
- Most system components are very stable thermally over an orbit
- Scan baffle only system component with a view to the ICT that has significant temperature variation

Temperature of the ICT and Scan Baffle



Temperature difference between ICT1 and Scan Baffle

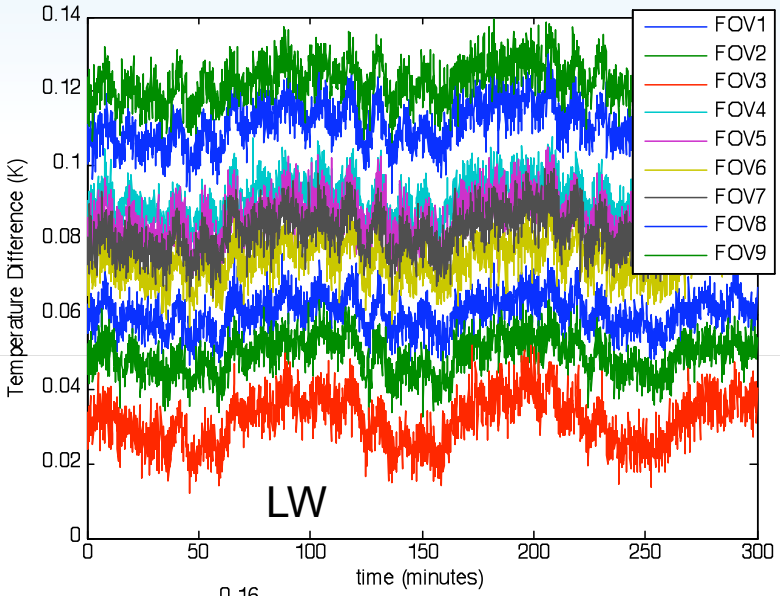


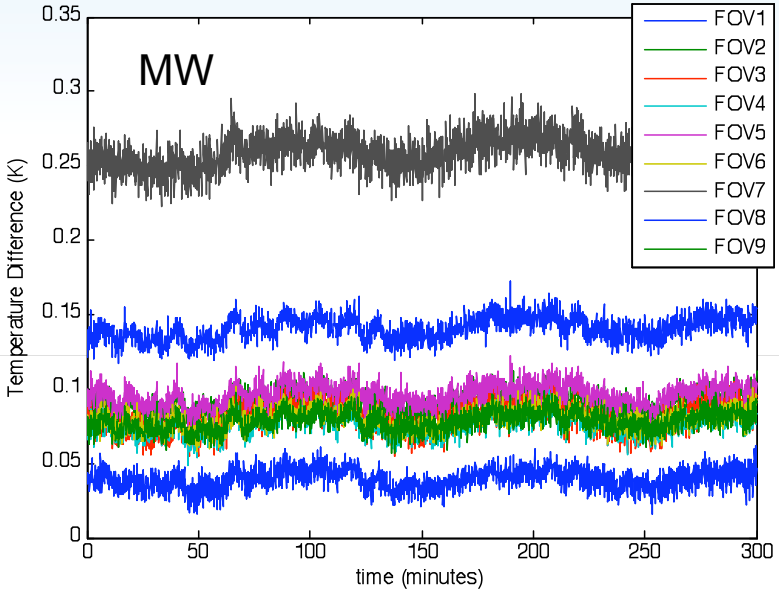
- Errors caused by reflected radiance from the scan baffle would be expected to correlate with temperature difference between the ICT and the scan baffle

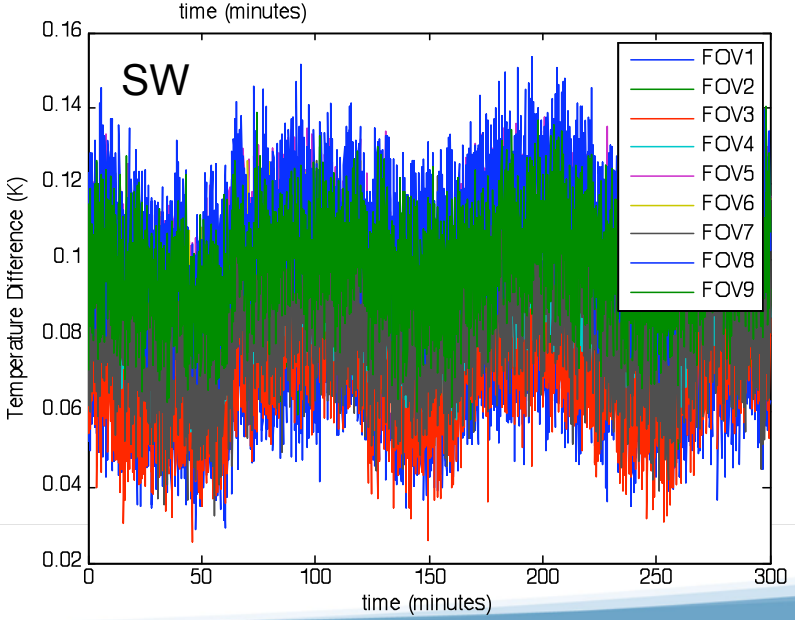
Radiometric Time History of Scan Scenario

- Spectra were spectrally averaged then plotted as a time history (spectral content averaged to give a single point for each spectra)
- The source was a constant temperature 287K ECT
- Variation of the CrIS measured brightness temperature with sensor temperature represents a radiance error
- ITT SDR_Generator version 2.18 with no ILS correction
- Nonlinearity correction coefficients taken from TVAC3
- Some FOV to FOV spread is also caused by temperature gradients in the ECT

Spectrally Averaged Time Histories

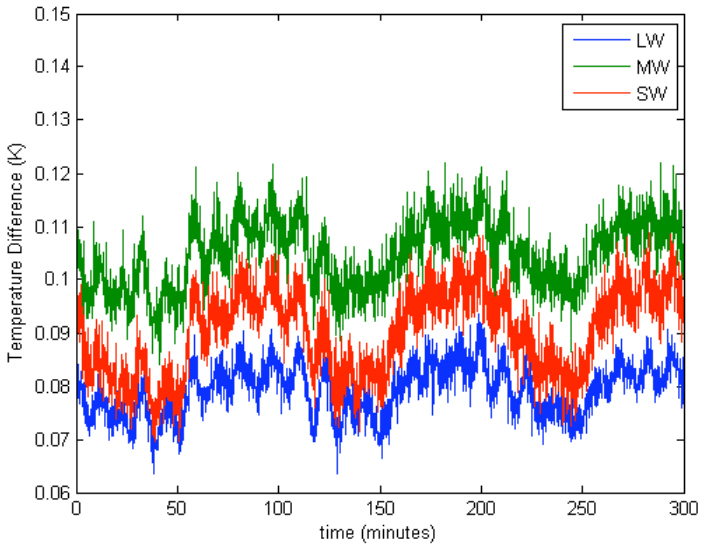


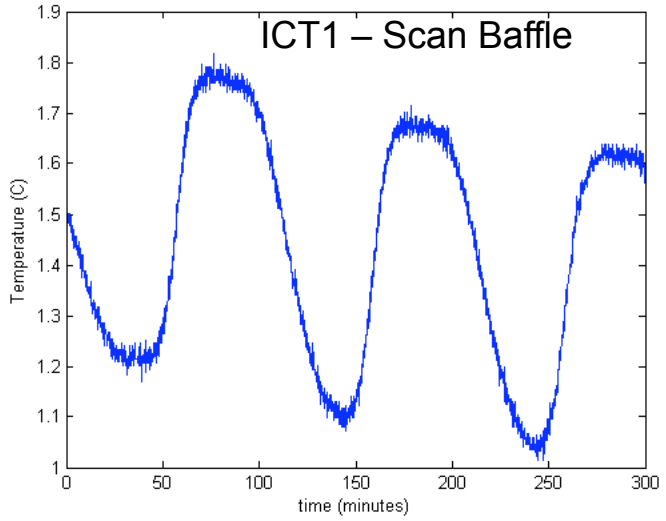




TVAC4 Scan Scenario Side 1

Radiance Errors Track ICT Scan Baffle Temperature Difference

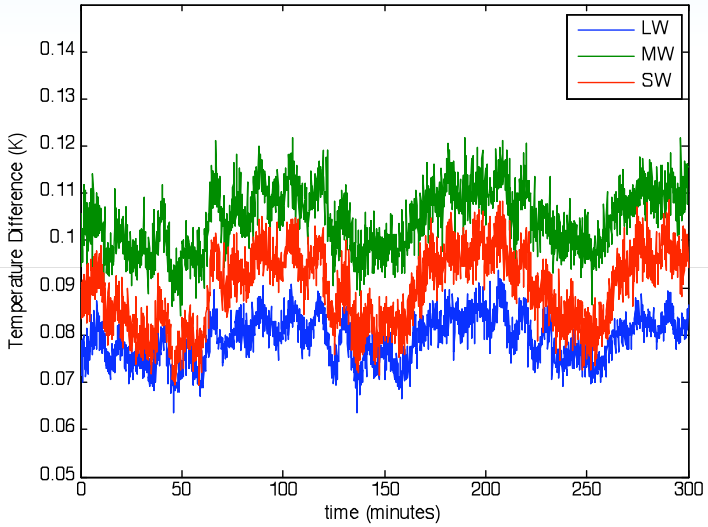




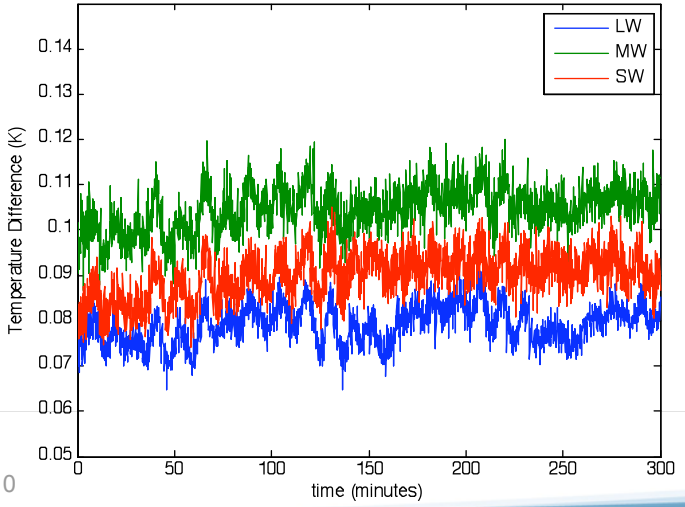
- All FOV averaged together
- Indication of radiance error being caused by reflections from the ICT
- Amplitude of radiance error for different bands follows ICT emissivity pattern
- ICT emissivity in SW is lowest so higher radiance error is expected
- Phase of radiance error tracks ICT minus scan baffle temperature

Radiance Error Nulled by Modifying the Scan Baffle Temperature

Original temperature profile

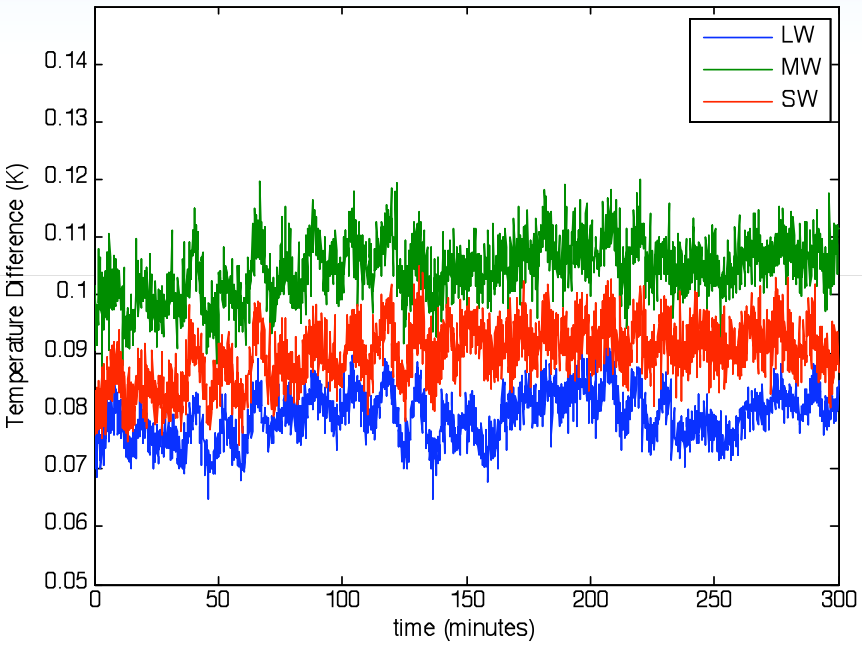


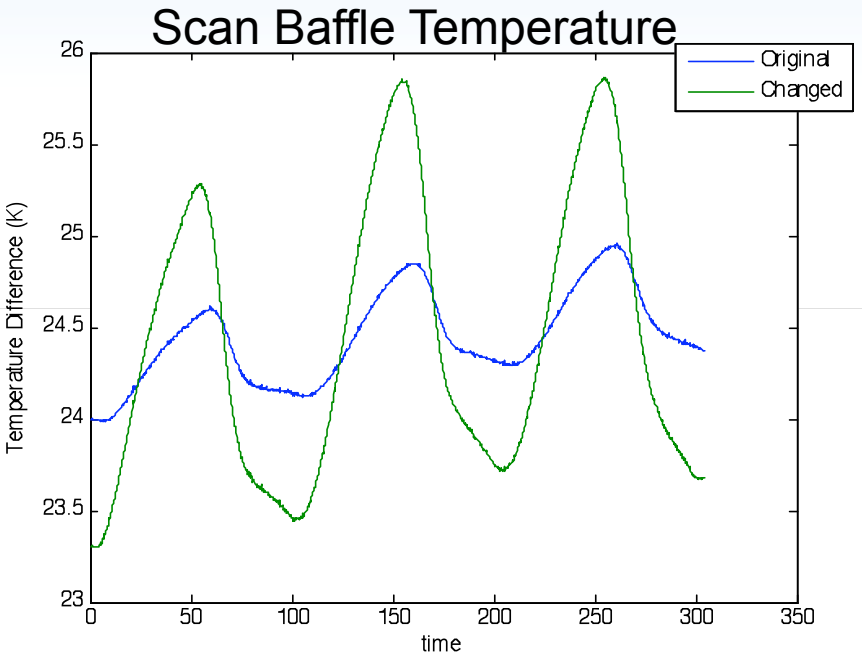
Modified temperature profile



- Scan baffle temperature sensor located on base of baffle insulted from temperature extremes
- Portion of scan baffle viewed by ICT is likely to have larger temperature extremes and change temperature faster than temperature sensor
- Scan baffle temperature profile modified and radiance recalculated

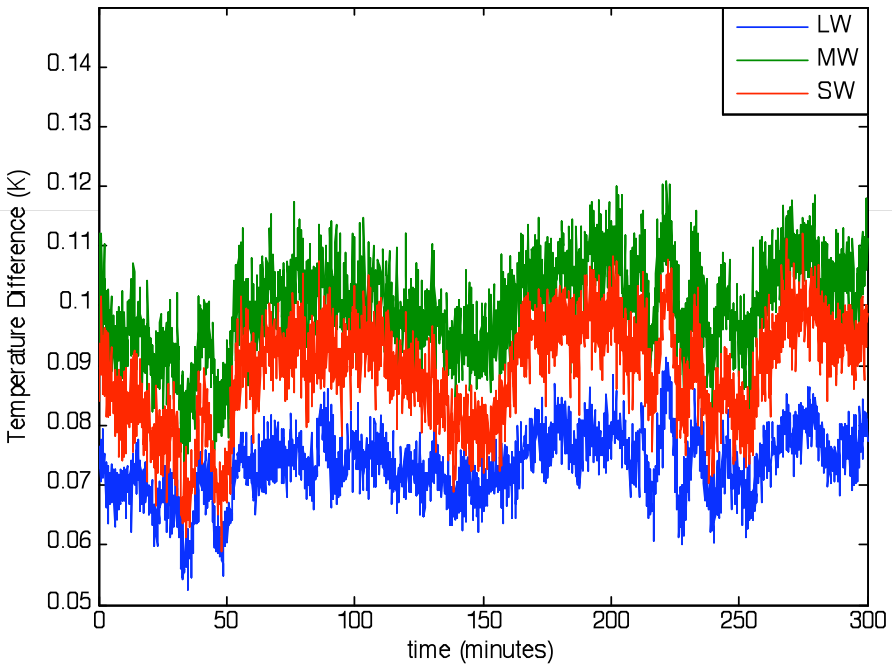
Modified Scan Baffle Temperature Profile Reduces Orbital Variation

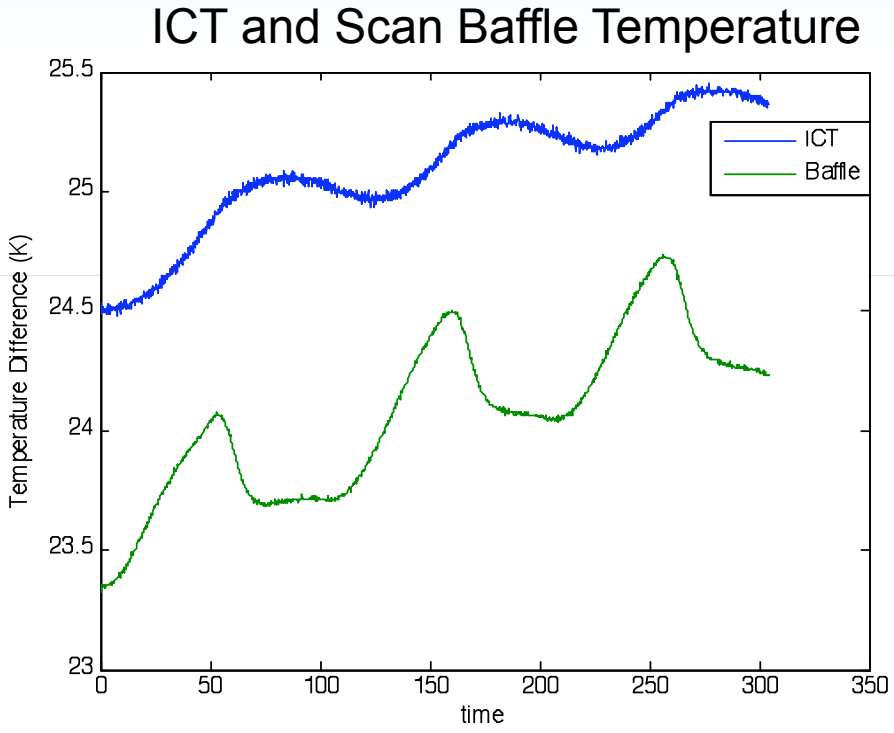




- AC part of scan baffle temperature profile increased by 1.03 K and phase adjusted to give a 6 minute time advance
- Correction for the LW and MW not complete
- ICT emissivity used in environmental model for the LW and MW too large

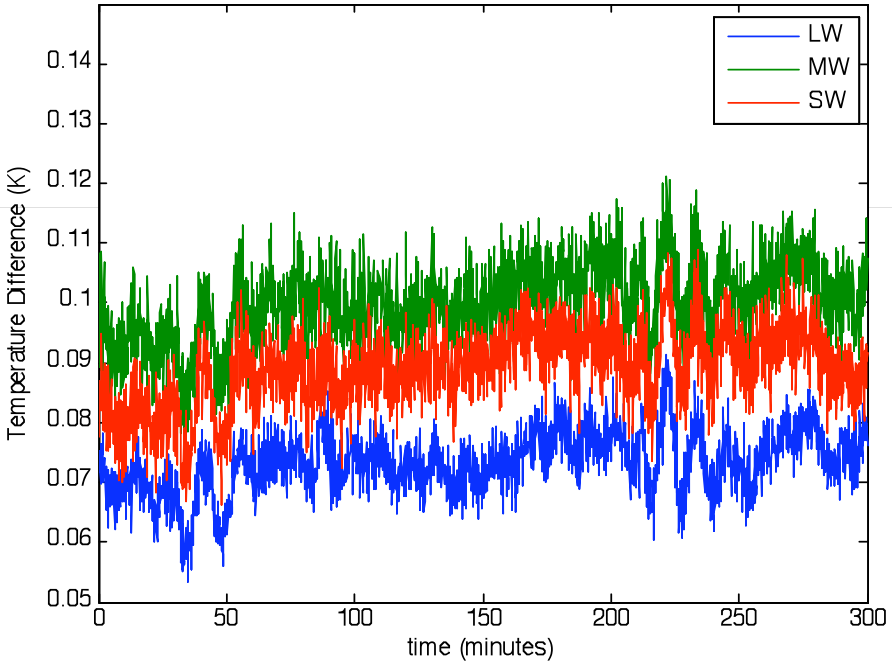
Side 2 Scan Scenario Results

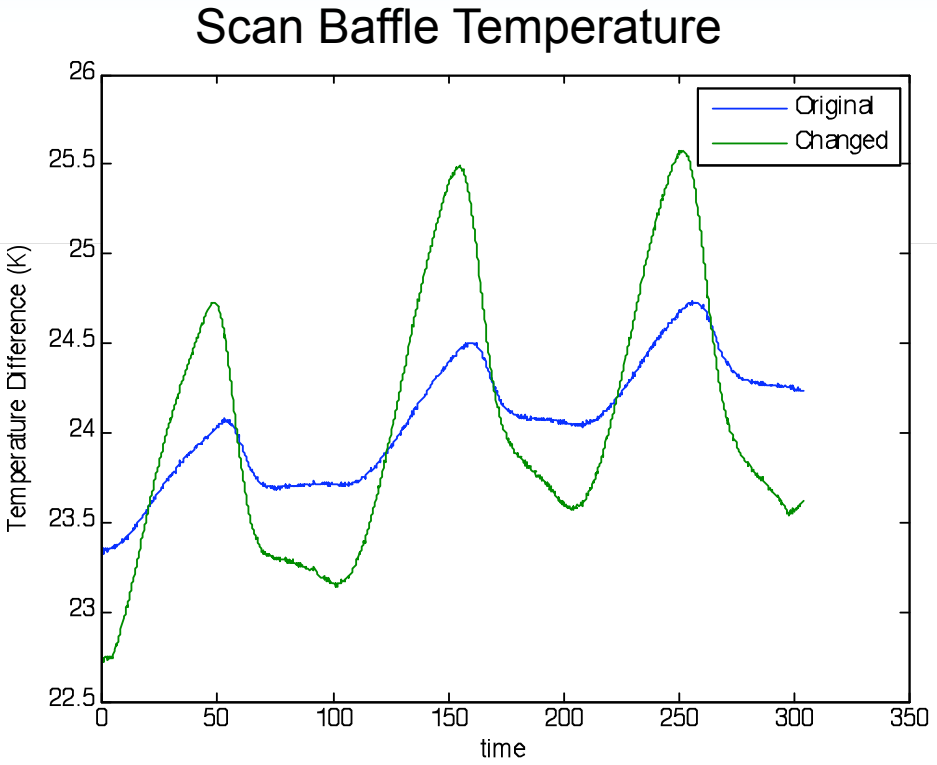




- Side 2 Scan Scenario results similar
- A little more ECT temperature variations
- ECT temperature variations are the same magnitude in each band

Side 2 With Modified Scan Baffle Temperature

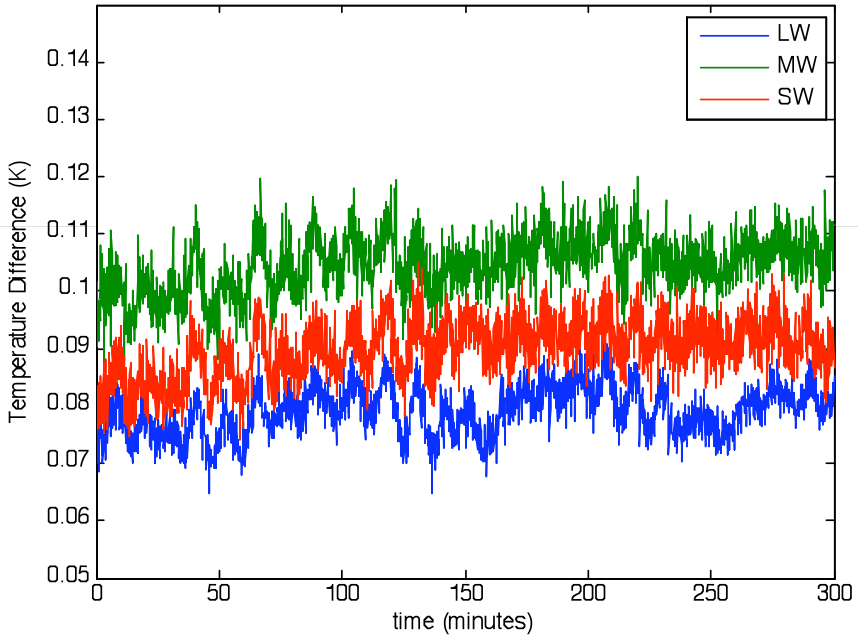




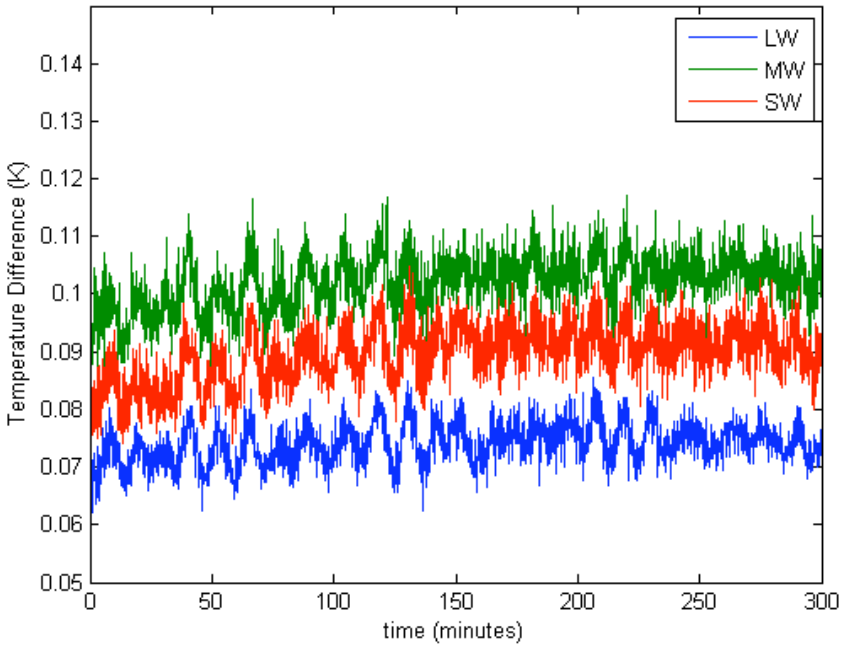
- AC part of scan baffle temperature profile increased by 1.03 K and phase adjusted to give a 6 minute time advance

Modifying ICT Emissivity Reduces Radiance Error

Modified scan baffle temperature



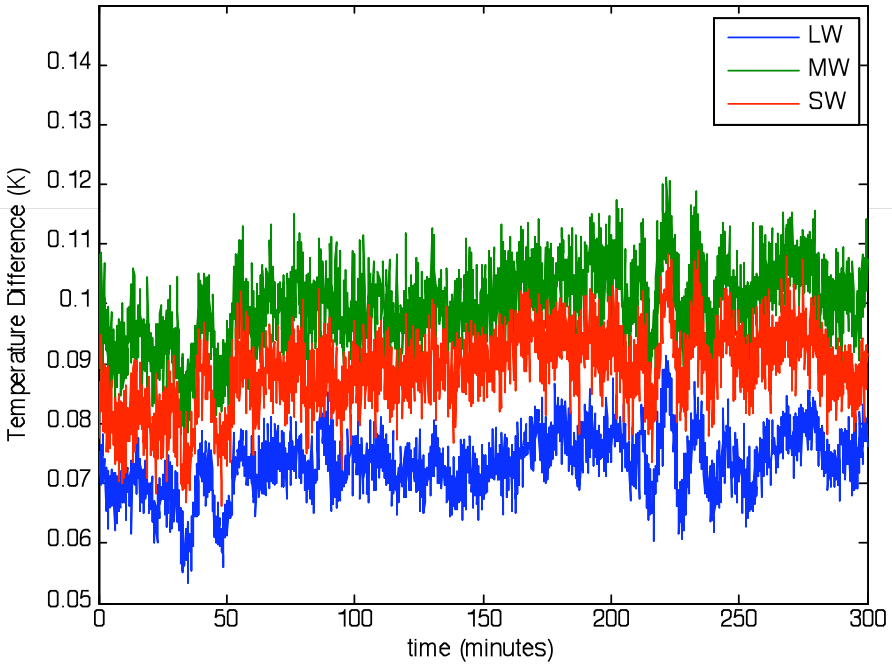
Also modifying ICT emissivity



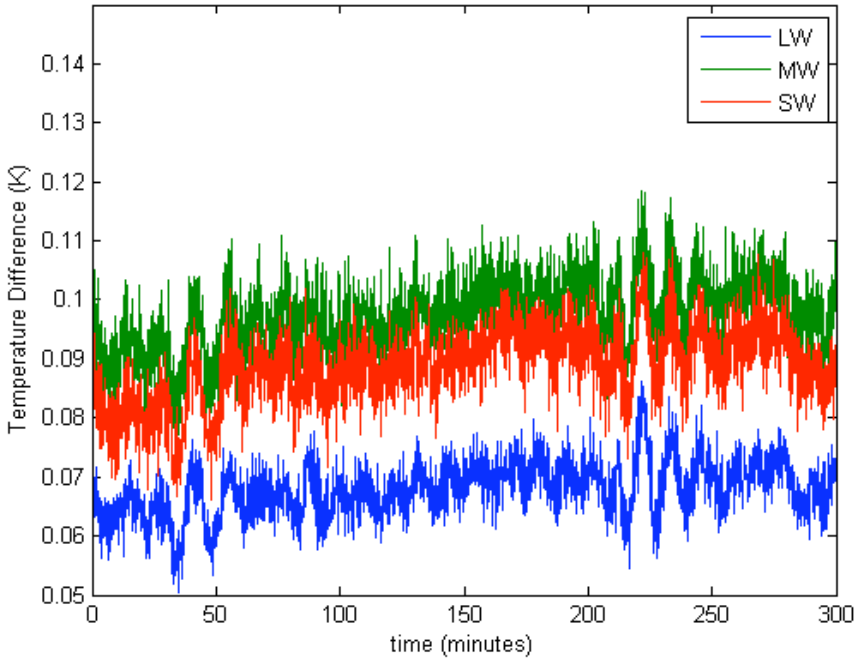
- Modifying the ICT emissivity as well as the scan baffle temperature profile reduces radiance error
- This is a band to band relative emissivity check not an absolute measurement

Side 2 Results are Similar

Modified scan baffle temperature

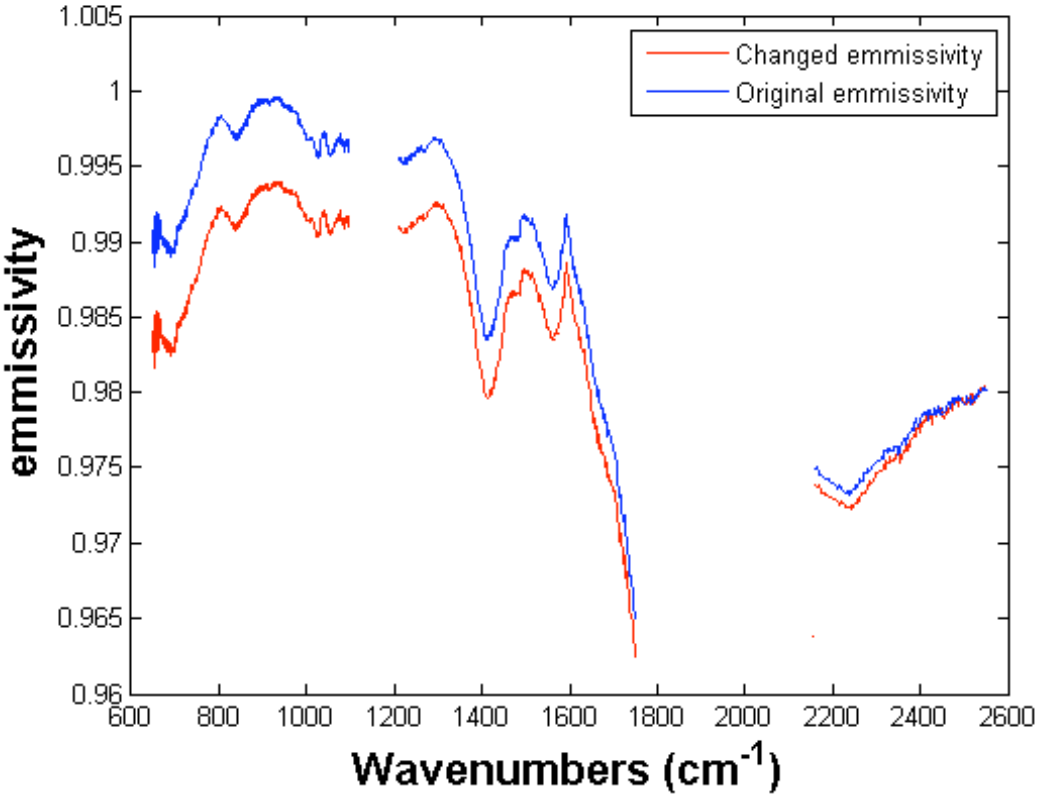


Also modifying ICT emissivity



- Modifying the ICT emissivity as well as the scan baffle temperature profile for side 2 produces similar results
- There is a little more ECT temperature variation for side 2

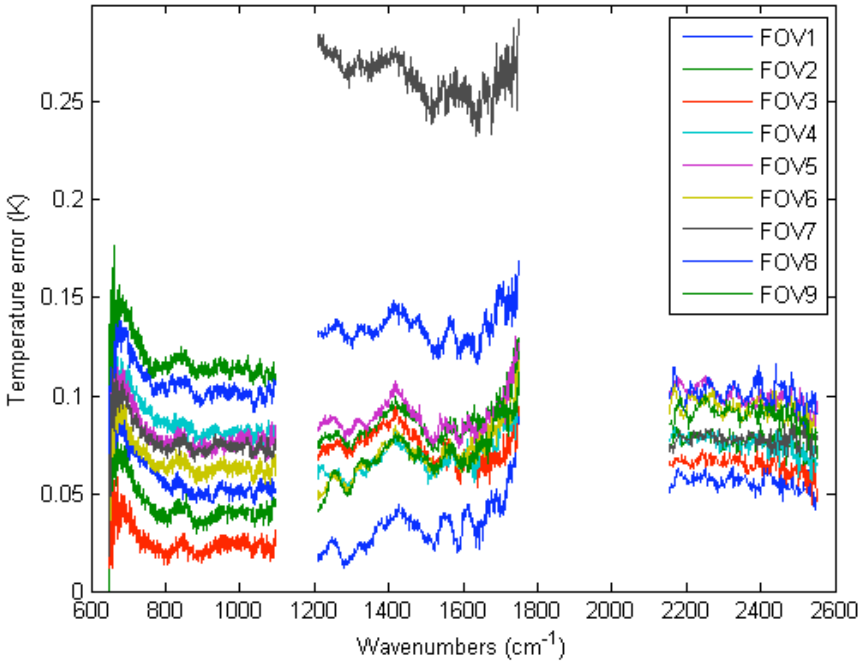
Modified Emissivity Reduces Radiance Error



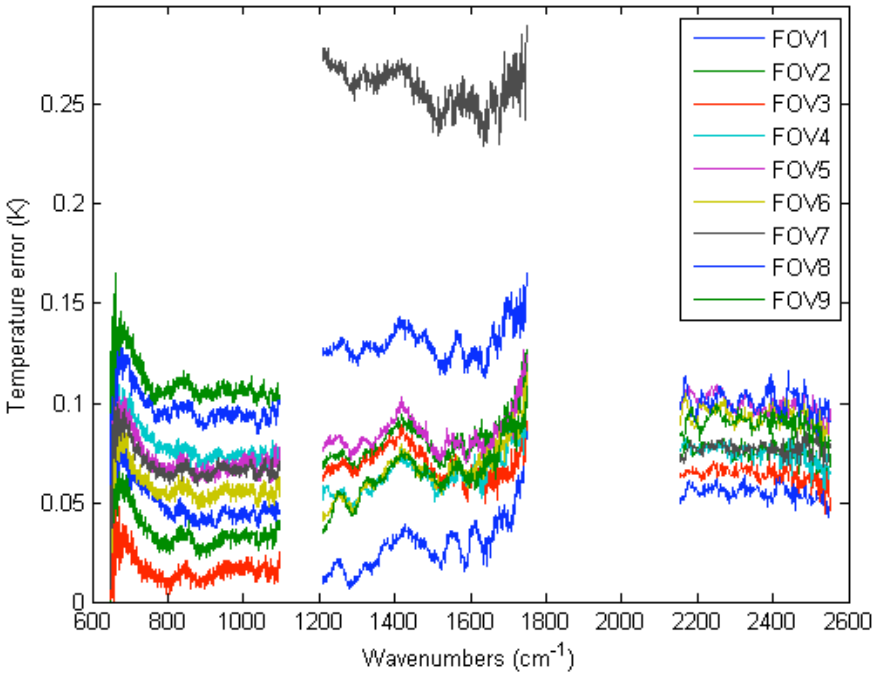
- Spectral shape of ICT emissivity determined by ITT using CrIS measurements
- ICT emissivity anchor point set in the SW band using radiometer measurement
- Engineering packet contains ICT emissivity
- Modification to ICT emissivity consisted of linear reduction of 0.0067 at the longwave end of band

Modifying ICT Emissivity Did Not Significantly Affect Radiometer Uncertainty

Original Emissivity

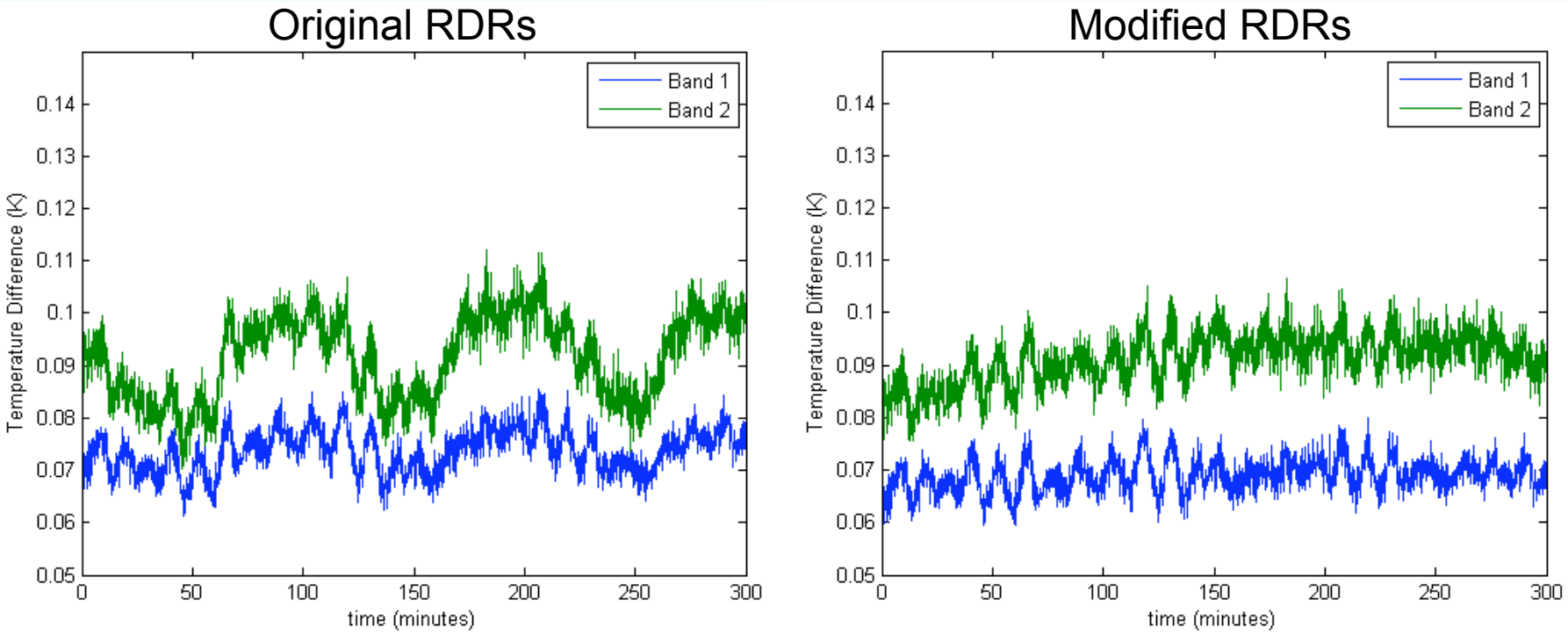


Modified Emissivity



- Emissivity modified by 0.0067 at end of LW band
- Not using latest nonlinearity a_2 coefficients
- No Scan baffle offset

Comparison of Bands with Different Emissivities



- Band 1: 860 – 1000 cm^{-1} (high emissivity)
- Band 2: 2155 -2340 cm^{-1} (lower emissivity)
- Scan baffle and emissivity modified as in previous slides

Alternative Approach: Solve for Scan Baffle Offset Temperature

- Many errors cancel to first order (especially relative errors)
  - ECT temperature
  - Nonlinearity
  - Radiance from component with stable temperatures
  - ICT temperature (non-time dependent)
- Assume remaining radiance error are caused by scan baffle temperature offset
- Sensitive to
  - Emissivity knowledge of ICT and ECT
  - ICT time dependent temperature knowledge (TVAC3 problem)
  - Environmental model errors
- Use extensive averaging to reduce noise

Linearized Version of Brightness Error

$$B_1 = T_{ECT} + S_{SB1}T_{SBoff} + S_{ICT1}T_{ICT}$$
$$B_2 = T_{ECT} + S_{SB2}T_{SBoff} + S_{ICT2}T_{ICT}$$

Where:

B_1 brightness temperature for band 1
B_2 brightness temperature for band 2
T_{ECT} temperature of the ECT
T_{ICT} temperature of the ICT
T_{SBoff} temperature of the scan baffle
S_{SB1} sensitivity of band 1 to the scan baffle temperature
S_{SB2} sensitivity of band 2 to the scan baffle temperature
S_{ICT1} sensitivity of band 1 to the ICT temperature
S_{ICT2} sensitivity of band 2 to the ICT temperature

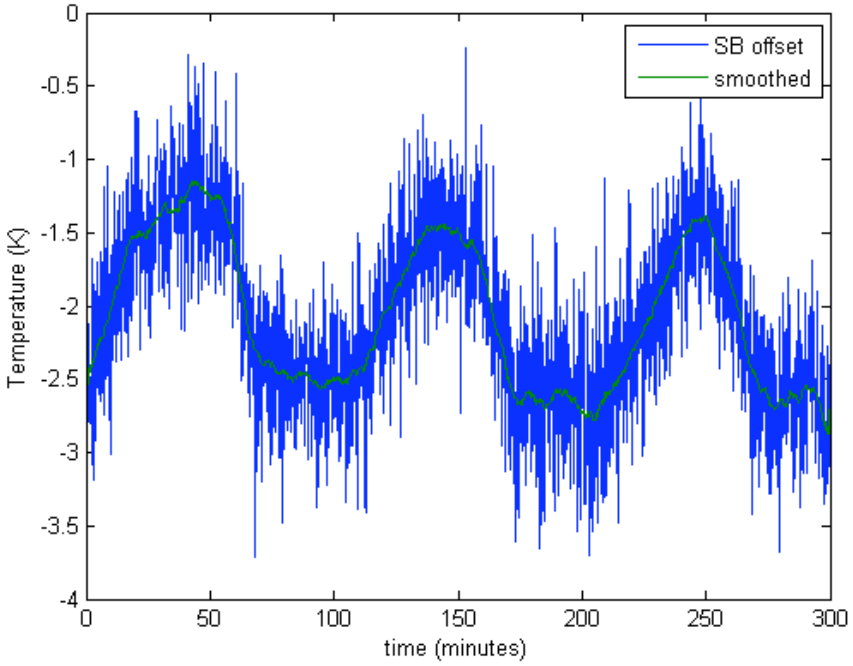
$$S_{ICT1} \approx S_{ICT2}$$

Solving for the temperature of the scan baffle offset gives

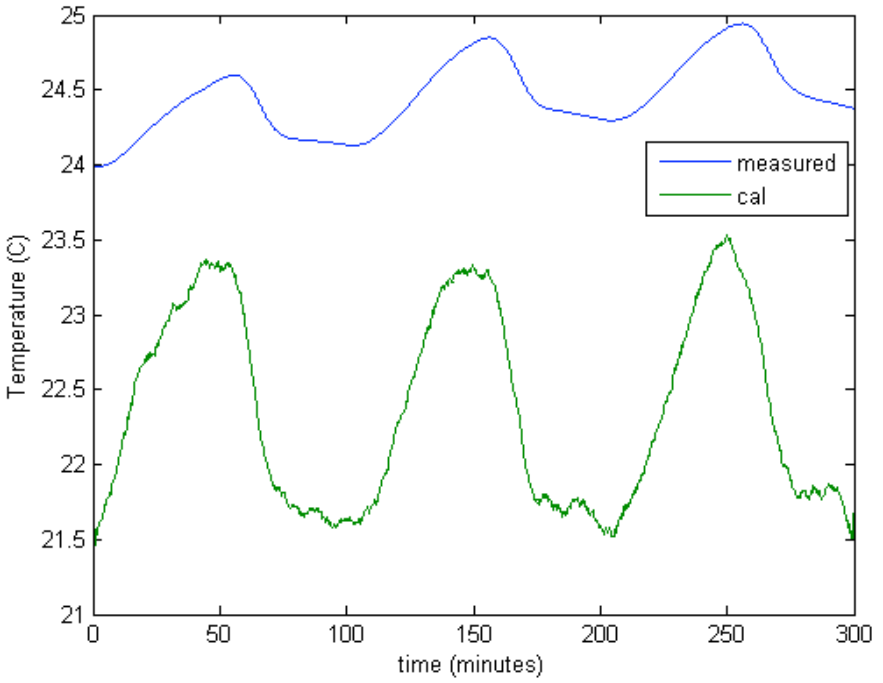
$$T_{SBoff} \approx (B_1 - B_2)/(S_{SB1} - S_{SB2})$$

Calculated Scan Baffle Offset

Scan baffle offset



Scan baffle temperature



- Calculated scan baffle temperature looks reasonable
- Absolute scan baffle offset temperature similar to ITT MN value of -2.5 K

Conclusion

- The CrIS sensor has completed thermal vacuum testing and is now being integrated with the spacecraft
- Extensive data averaging makes possible the detection of small radiance error during the scan scenario test
- Modification of the scan baffle temperature profile reduces this error
- Indication that the LW ICT emissivity in the engineering packs is slightly too high relative to the SW emissivity
- Reasonable scan baffle temperature calculated from scan scenario radiance error
- A time varying scan baffle temperature offset is planed for use on orbit